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The Current State and Path Forward For Enterprise Image Viewing: HIMSS-SIIM Collaborative White Paper

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Abstract Clinical specialties have widely varied needs for diagnostic image interpretation, and clinical image and video image consumption. Enterprise viewers are being deployed as part of electronic health record implementations to present the broad spectrum of clinical imaging and multimedia content created in routine medical practice today. This white paper will describe the enterprise viewer use cases, drivers of recent growth, technical considerations, functionality differences between enterprise and specialty viewers, and likely future states. This white paper is aimed at CMIOs and CIOs interested in optimizing the image-enablement of their electronic health record or those who may be struggling with the many clinical image viewers their enterprises may employ today.

Keywords Cardiac imaging · Cardiology PACS · Clinical image viewing · Diagnostic imaging · Enterprise imaging · Digital imaging and communications in medicine (DICOM) · Electronic medical record (EMR) · Enterprise PACS · Image display · Image distribution · Image viewer · Imaging informatics · Integrating healthcare enterprise (IHE) · Multimedia · PACS

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What Is An Enterprise Viewer?

Every physician, nurse practitioner, physician assistant, nurse, and imaging technologist of a health organization needs to review and manipulate images, image metadata, and associated imaging reports through the electronic health record (EHR) as part of routine activities. Patients are interested and increasingly savvy enough to navigate their own diagnostic images. Given the wide spectrum of EHR users and related patient care needs, there is a similarly wide spectrum of images and video that must be accessed, reviewed, and manipulated [1, 2]. This spectrum includes DICOM diagnostic images common to cardiology, obstetrics, radiology, and other specialties [3]. It includes procedure and point-of-care documentation images across all modalities and specialties, such as from endoscopy, handheld dermatology camera, consumer mobile camera, point of care ultrasound and fluoroscopy, and emerging pathology formats [4–15]. Finally, health organizations frequently make some forms of scanned paperwork documentation available throughout the EHR via image viewers. To meet the enterprise viewing needs of many clinical users to review many content types within an enterprise electronic health record, enterprises are looking to a single multipurpose application, an enterprise image viewer.

Recently, a collaborative workgroup made up of members from the Healthcare Information and Management Systems Society (HIMSS) and the Society for Imaging Informatics in Medicine (SIIM) was formed to identify best practices and offers potential solutions for the challenges associated with enterprise imaging. The larger workgroup was split in to subgroups, each tasked with a different aspect of enterprise imaging. This subgroup focused on enterprise viewing.

For the purpose of this white paper, we propose the definition of an enterprise viewer as, "a thin-client or zero-client application used on any off-the-shelf device to distribute, display, and manipulate multi-specialty image, video, audio, and scanned documents stored in separate centralized archives through, or standalone from, the EHR." Note that most legacy picture archiving and communication systems (PACS) have an associated thin-client or zero footprint application, but this may not provide diagnostic interpretation capabilities, the ability to look to a non-PACS archive, adequate speed, or the toolset depth of the full version. A traditional full version PACS typically includes local storage of images, tailored specialty specific diagnostic tools, a higher degree of operational specialty workflow support, but more limited features for viewing from within EHR context [16]. The purpose of this white paper is to describe the reasons for enterprise viewer growth, enterprise viewing technical infrastructure, viewer classifications, and viewer toolsets.

Enterprise Viewer Growth

The need for enterprise viewers has grown alongside the expansion of electronic health records [17]. With an EHR implementation enterprises may restructure their support model away from a medical specialty focused approach with limited governance towards a model with engaged governance, clinical service lines—including enterprise imaging—and enabling services, such as scalable application delivery, data warehousing, storage, network, and the service desk [18, 19]. Some common EHRs do not provide integrated image storage or a multi-specialty/multi-format image viewer. As a result, many health systems seeking greater integration of care records consolidate clinical documentation, orders, formularies, charges through EHR implementation, but may not address longstanding specialty image capture, storage, distribution, or viewing siloes.

A single enterprise image repository containing all clinical multimedia has become a goal of many health enterprises [20, 21]. This permits a single integration point for the electronic health record to find images and a scalable central storage solution for optimal maintenance and cost. Most organizations store images across many clinical archives at the time of EHR implementation. There may be separate archives within each specialty, or even multiple archives within a single imaging-heavy specialty such as radiology in one consolidated health system. Given that, enterprises have the option of interfacing their many legacy viewers into their EHR for widespread image accessibility or using a single enterprise viewer that can query federated archives. The latter is the common choice due to ease of support and the clinical satisfaction of a consistent application to manipulate all images, rather than forcing familiarity with many disparate location and specialty-specific viewers.

Enterprise viewers can fulfill many clinical use case gaps facing hospitals today. Enterprise viewers can solve needs for the following:

- Single viewer access from the EHR, integrating clinical documentation with images stored in many storage archives [22, 23].
- Integrating many forms of "non-traditional" clinical still image and video content not viewable in some traditional enterprise PACS today, such as from pathology, handheld cameras, and endoscopes [24, 25].
- Diagnostic image interpretation by specialties and clinics without a dedicated PACS, using an application of high quality and often with some advanced image data manipulation functionality.
- Physician to physician collaboration, as some enterprise viewer applications offer teleconferencing capabilities while sharing the image viewer interface [26].
- Point of care secure mobile device image access for providers to review and discuss findings with patients and families in the hospital without being tied to a hardwired workstation [27–30].
- On-call provider image review in their home or office.
- Patient portal image viewing [31, 32].
- Referring physician or telehealth portal image viewing.
- Some medical learner education and research image viewing [33].

Enterprise Viewer Technical Considerations

Overview of Data Flow and System Design In the past, installation and support costs to deploy PACS clients on thousands of enterprise desktops for basic image viewing often outweighed realized or potential benefit. With more and more viewers today requiring only minimal client-side technology and maintenance, and more consistent end workstation configurations to support EHR deployment, much lower support costs justify clinical wins from image distribution. Today, most enterprise viewers transmit imaging studies from the archive to a rendering server and/or short-term cache, where the data is accessed by an end user on a desktop, laptop, or mobile device. In the transmission, many enterprise viewers convert the original format, usually DICOM, to lossy or lossless non-DICOM formats. This has many advantages over traditional designs. For example, displaying smaller non-DICOM data is faster than displaying the same image in DICOM format. The method of transmission also permits playback to proceed while subsequent data is still being received. This is a significant development as image data storage needs across enterprises increase, such as from emerging digital whole slide pathology, DICOM radiology dataset bloat, and operative suite video expansion [34, 35]. After data transmission, many enterprise viewers reduce the resolution of the image on the server and send a rendition appropriate for the device and screen requesting the imaging, including to mobile devices. If the user zooms in on the image, the larger image is retrieved and rendered.

Dependencies Some provider users, such as radiologists, tend to have a consistent and optimized image viewing environment. Some, such as cardiologists, may present images in high-light or low-light environments, and on a variety of off-the-shelf workstations and monitors. Ideally, an enterprise viewer presents images in the ideal state for the environment and user without manual intervention. Enterprise viewer technology is developing quickly and toward having fewer client side dependencies. Current iterations often do not require the plug-ins or runtime environments of older versions. The higher-functioning viewers require an HTML5 compatible browser and are usable on most desktop and mobile operating systems. Compared to a full legacy PACS client, enterprise viewers often offer similar presentation of large sets of still image and video data with minimal latency and consistent playback framerate, but fewer requirements on local browser, RAM, and central processing unit.

Security Devices can get lost or compromised, whether it is a hospital device or one at a provider's home. Security improves when the viewer converts image data into non-DICOM formats at the time of display and does not require composite DICOM data and metadata transfer to the local device. Some enterprise viewers today support client side cache lifecycle management policies, deleting content immediately after its presentation and preventing image content from being retained on the device. Viewers should use secure connections and offer built-in encryption. Enterprise viewers are accessed either separate from the EHR via secure authentication or through existing EHR authentication. Providing access to the enterprise viewer only through the EHR permits EHR access control policies to be enforced before the viewer is called, akin to access controls employed in referring physician, health information exchange, and patient portal applications. EHR level access controls to specific data types may be important in cases where more complex rules governing viewing are necessary, such as for consent directives, child abuse images, or plastic surgery images. Institutions may require two-factor authentication for electronic health record and/or enterprise viewer use. Enterprise viewers will often provide audit records, such as the method defined in the IHE Audit Trail and Node Authentication (ATNA) integration profile [36]. Even with these controls, however, with the ease of screen capture on today's devices, no enterprise viewer offers complete risk avoidance for losing medical imaging PHI.

Integration Stage 2 Meaningful Use offers a menu set measure incentivizing certified electronic health record technology image integration [37]. Enterprise viewer integration may require third party integrations to several enterprise specialty PACS viewers, potentially a vendor neutral archive, one or more information systems or electronic health records, document storage, as well as reporting and workflow tools. Common EHRs launch the enterprise viewer browser at the study level via URL or secure URL in inline frame through an API (Application Programming Interface). With this approach, the enterprise viewer becomes a clinical reference tool, a seamlessly integrated extension of the EHR. Many enterprise viewers can also launch an API to a specialty PACS viewer if an imaging finding requires deeper interrogation. Viewers can be configured to accept a result interface (HL7 ORU) or call a results web service for users accessing the enterprise viewer outside the EHR to review the interpretation if needed [38].

Differentiators Important decision levers for choosing an enterprise viewer today include efficient usability (especially by those who are not comfortable manipulating image data), mobility, breadth of advanced and specialty toolset functionality, security, speed of full dataset presentation, and affordability. Within a hospital environment, generally, the support and implementation differences between thin-client and zero download browsers are small enough that they are not significant product differentiators. Zero download browser-based viewers may sacrifice slightly on speed, though the small difference may not be noticeable or relevant to end users. If speed is adequate, generally no download applications are slightly preferable for end users with mobile devices because they do not require manual updating on personal devices.

Enterprise Viewer Regulation

The FDA calls "mobile platforms" commercial off-the-shelf computing platforms that are handheld in nature, such as smart phones, tablet computers, or other portable computers [39]. A "mobile medical application" is a software application that can be executed on a mobile platform or tailored to a mobile platform but executed on a server. According to the FDA, a mobile medical app is a mobile application that is either intended to transform a mobile platform into a regulated medical device or is to be used as an accessory to a regulated medical device. Enterprise viewer mobile application vendors pursue Food and Drug Administration (FDA) classification as a 510(k) Class I or Class II medical device [40]. At a high level, class I devices, such as medical exam gloves and bandages, are subject to general controls sufficient to protect the user and are low risk of harm to users. Class I enterprise medical image viewing devices are generally cleared for image review. Most devices used for medical diagnosis and treatment decisions that are FDA Class II cleared have undergone a more rigorous objective quality evaluation through Premarket Notification 510(k). Class II classification, such as used in imaging modalities and most specialty PACS viewers, requires more stringent controls for performance and design. With telemedicine growth internationally, many enterprise viewer mobile app vendors have sought diagnostic classifications similar to FDA Class II outside of the US. Outside of previously mentioned access controls, it is difficult for health organizations to predict how and when the enterprise viewer would be used for diagnosis and treatment, rather than image review, for research viewing, or for medical education. Thus, those viewer vendors with a broad spectrum of full and mobile version FDA Class II and global clearances across the many imaging specialties and modalities may have a competitive advantage in that their solutions have been evaluated more intensively and may offer mitigated risk to the institution.

While many physicians capture and review images via mobile device, it is believed few physicians today perform true diagnostic image interpretation on mobile devices because of limited screen real estate, gesture functionality, and operational workflow support. Physicians do however use mobile devices to review images obtained by another department or division, access images away from the hospital, and enrich a doctor-patient consultation with image findings review. At present, IHE technical guidelines apply primarily to DICOM images. As medical imaging expands to include photographs and other media types, mobile devices may be well suited for diagnostic interpretation of this subset of media. The Integrating the Healthcare Enterprise (IHE) integration profiles for Basic Image Review (BIR) and Consistent Presentation of Images (CPI) begin to describe screen calibration necessary for predictable display of softcopy images on diverse devices and may notify a user when the hardware the images are displayed through is not adequate for diagnostic use [41, 42]. Currently, the FDA lists mobile apps intended for image display (such as for multi-disciplinary patient management meetings, rounding, and patient consultation), rather than diagnostic image viewing, under those apps generally subject to enforcement discretion today; these devices are considered medical image communication devices if they include a persistent on-screen notice, such as "images for informational purposes only and not intended for diagnostic use." [39, 43]

Enterprise and Specialty Viewer Toolsets

While specialty PACS viewers and enterprise image viewers have evolving and often very similar technical requirements for personnel support, infrastructure, accessibility, reliability, and security, there are significant clinical differences to appreciate. Many definitions of an enterprise viewer have proliferated because of this overlap and evolution, and because "enterprise" is a favorable buzzword today. Related, the term "universal viewer" is often used synonymously with enterprise viewer in vended products today. "Universal viewer" may imply that any non-text format or content is viewable via the application or that the application would meet any and all clinical needs. No viewer can present every single format used today or to be developed in the future. We call the applications "enterprise viewers" rather than "universal viewers" throughout this white paper for these reasons.

In general, enterprise and specialty viewers support basic, advanced, specialty diagnostic, and workflow toolsets. Products today are very much in evolution. Some enterprise viewers have quite mature functionality of all four and are marketed as specialty PACS replacements in addition to enterprise viewers. Some enterprise viewers today only include basic tools and perhaps a few advanced tools. Some applications marketed as enterprise viewers transitioned out of a single specialty viewer application and have basic tools, a preponderance of one subspecialty of advanced and specialty tools, with an absence of others.

By definition, enterprise viewers are designed to meet image and video review and manipulation needs of a large group of users. No single viewer will meet every provider, technologist, or administrative need today or in the future across all medical specialties (Table 1). In general, enterprise viewers serve the needs of image consumers better than diagnostic image producing specialties. Diagnostic imagers have deeper and more technical advanced, specialty, and workflow toolset needs that are often out of scope for enterprise viewers. Thus, even with an enterprise viewer, most health care organizations should plan on having at least some specialized applications for more technically or clinically challenging diagnostic use cases. Note that higher cost enterprise viewers often are more inclusive of advanced, specialty, and workflow toolset needs.

Basic Toolsets Basic tools are functions that many imaging and non-imaging specialties, as well as nurses, technologists, and patients would be expected to use for image manipulation on many content types. All enterprise viewers today have these "commodity" components, with generally little variability in their use, but much variability in their layout and on-demand accessibility. Basic tools include current exam and prior exam image and series navigations; pan; rotate; zoom; distance and angle measurement; window-level; cine controls; report display controls and many others. Some tools are outlined in part in the IHE Basic Image Review (BIR) integration profile, though providers will have much more detailed requirements for enterprise viewer functionality and

Table 1 Commonly addressed use cases and commonly not addressed use cases by an enterprise image viewer

Specialty/location	Enterprise viewers commonly accommodate review of..	Enterprise viewers may not include…
Cardiology	Echocardiography; MRI; fluoroscopic and CT angiography	Advanced and specialty toolset functionality and calculations, such as nuclear cardiology gated SPECT image and ECG integration, ejection fraction determination, coronary vessel tracking, and structured data export for reporting
Dermatology	Most handheld camera images	Efficient presentation of salient image metadata, such as laterality and anatomy
Gastroentology	Fluoroscopy; endoscopy; image-based reports	Image-based report creation
HIM	Most scanned documents	(None)
Mobile device users	Many image sets needing only limited manipulation or interactivity with the user at point of care or off site	Advanced and specialty toolset functionality and calculations; adequate image resolution, ease of use, or screen real estate
Obstetrics and gynecology	Endoscopy; hysterosalpingography; fetal and gynecologic ultrasound	Advanced and specialty toolset functionality and calculations, such as 3D/4D imaging, growth chart tracking and dating
Ophthalmology	Orbit ultrasound; secondary captures such as from retina and slit lamp modalities	Advanced and specialty toolset functionality and calculations, such as optical coherence tomography and automated image-based biometry; presentation of many proprietary image formats
Pathology	Gross sample intake and prep; secondary captures from whole slide, FISH, and cytogenetics	Advanced and specialty toolset functionality and calculations, such as common lab automated image-based cell counting and percentage analyses; adequate whole slide rendering speed; presentation of many proprietary image formats
Patient portal	Most images of interest to patients	Ease of use necessary for patient population deployment; image/exam data download
Preoperative planning	Operative template secondary capture	Operative template creation
Radiology	Radiography; ultrasound; MRI; CT; fluoroscopy	Advanced and specialty toolset functionality and calculations, such as breast tomography, tissue perfusion, dataset fusion, standard uptake value determination, image registration, lesion tracking, and structured data export for reporting
Referrer portal	Most images of interest to primary care	Many needs not met for subspecialists, such as those above
Research	The established use cases above	Advanced and specialty toolset functionality and calculations being investigated

usability than this profile outlines [41]. The BIR profile may need refreshing given recent advances in technology.

Advanced Toolsets The IHE Basic Image Review profile distinguishes "Advanced" image processing functions, such as surface rendering, volume rendering, centerline placement, multi-modality fusion, multi-planar reconstruction (MPR), bone removal, maximal/minimal intensity projection (MIP/MinIP). Many of these tool sets were originally designed primarily for radiologic and vascular imaging and do not have a correlate in other types of enterprise imaging.

Advanced tools often permit easy manipulation of large DICOM datasets of content to gather new perspectives and conclusions. These tools are often the primary differentiators across vendors providing enterprise image viewers. Advanced tools are typically used by the imaging service creating the images and those specialties adept with imaging planning a surgical intervention. Primary care practitioners typically will not develop deep familiarity with advanced tools, as they would be only used infrequently in their practice. As functionality becomes more widespread across vendor solutions and across clinical user bases, advanced tools grow to become increasingly basic and commoditized, such as enterprise viewers more and more commonly offering multi-planar reconstructions of coronal and sagittal views from isotropic axial datasets.

Specialty Toolsets Specialty diagnostic tools are image data manipulation features typically only required by the specialty creating the images. Cardiology stress/rest ECG raw waveform and metadata ingestion, obstetric fetal growth calculations, orthopedics pre-surgical planning templates, ophthalmology corneal topography biometry, pathology whole slide imaging, lab image-based cell count and percentage calculation, and radiology anatomic and perfusion calculations all generally are only needed by the performing specialty; enterprise viewers often do not include functionality for most of these use cases. Modality vendors develop new diagnostic image data capture technology and physiologic calculation tools regularly and often require a dedicated same-vendor proprietary specialty viewer in early development. Promising capabilities in imaging deep learning and computer vision will likely be piloted in specialty toolsets and grow more widespread over time towards enterprise viewer use.

Some specialty toolset features are not specific pieces of image manipulation or biometric calculation functionality, but instead highly configurable and optimized diagnostic display protocols for the task at hand. These display protocols may be defined first at a modality or procedure specific level and then assigned to a role or user level for efficient diagnostic image review. Preferred and required mouse, keyboard, and hotkeys configurations for image consumption vary between specialties, between modalities, and between exams with high and low still image and cine stacked image counts. Even within the same modality, image interpretation workflows vary. Echocardiography interpretation, for example, places a much higher value on cine controls such as pause, run, frame step forward/backward, and next/previous loop, than other procedures or specialties, including most radiology sonography. Even though cine functionality is a "basic tool" as described by IHE BIR above, its value to diagnostic echocardiography studies requires that it not only be available during study review, but also that its controls are very easy to access by cardiology specialists. Often echocardiography cine clips are played automatically upon screen presentation. This is intuitive because the heart is a moving structure and to gather adequate conclusions, its ultrasonographic motion must be studied. Automatic playing of ultrasonographic cine clips in radiology in many cases however would not be preferred, such as sonographer sweeping over a broad anatomic region of concern, or cine scanning stationary while demonstrating particle motion inside an abscess. Depending on the monitor display used, echocardiography providers may prioritize top-to-bottom screen real estate rather than left-to-right, requiring images to display in the maximum vertical dimension. This means image play controls, current series thumbnails, and any prior exam timeline may be preferred on the sides of screens, which is not typical in enterprise viewers oriented towards radiology use or even those configured for coronary CT or coronary catheter angiography. Presenting effective graphic user interface orientations and user controls is further challenging when concomitantly viewed current exam modality and prior exam modality differ. It is made yet more challenging when images must be consumed together with scanned documents such as electrocardiograms or text elements such as vital signs, medication administered, or performing technologist notes. Enterprise viewer capabilities in specialty toolsets are being developed quickly and with broad physician input and prioritization [44].

Workflow Toolsets Workflow tools are those that assist with day-to-day management of an imaging enterprise or imaging finding communication. Workflow tools within enterprise viewers vary substantially. Some EHRs and third-party applications may solve the clinical need for workflow toolsets, such as reading worklists and departmental peer review, alongside enterprise viewers [45]. Some enterprise viewers incorporate provider-to-provider real time text and video chat or teleconferencing for synchronous imaging study collaboration; these collaboration tools may be only within an organization or may be configured with image sharing capabilities outside the organization. Workflow tools tied to specialty PACS or enterprise viewers may also include integrations for voice dictation and structured data passage to downstream systems [46].

Conclusion

Many providers will anecdotally cite that sometimes an EHR textual description of images, whether documentation images in dermatology or diagnostic ones in radiology, is less valuable than seeing the images themselves. This HIMSS-SIIM white paper defines an enterprise viewer and provides high-level technical, regulatory, and functionality considerations when evaluating these applications. Enterprise viewers serving multiple specialties and use cases have gained favor for many reasons. These reasons include institutional pressures favoring scalable infrastructure, the business need presented by electronic health record image storage and viewing, data flow standard advances, viewer toolset improvements, and others. While specialty viewers will always be necessary to review high complexity imaging patient care and to handle some of the unique needs of diagnostic imaging specialties, overall their role as the backbone of imaging care within an enterprise may grow less common. Choice of an enterprise viewer for EHR image review should include a multi-specialty provider evaluation and adequate oversight. Further enterprise viewer expansion is expected to cover the broad needs of provider, non-provider staff, and patient image access and viewing in coming years.

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